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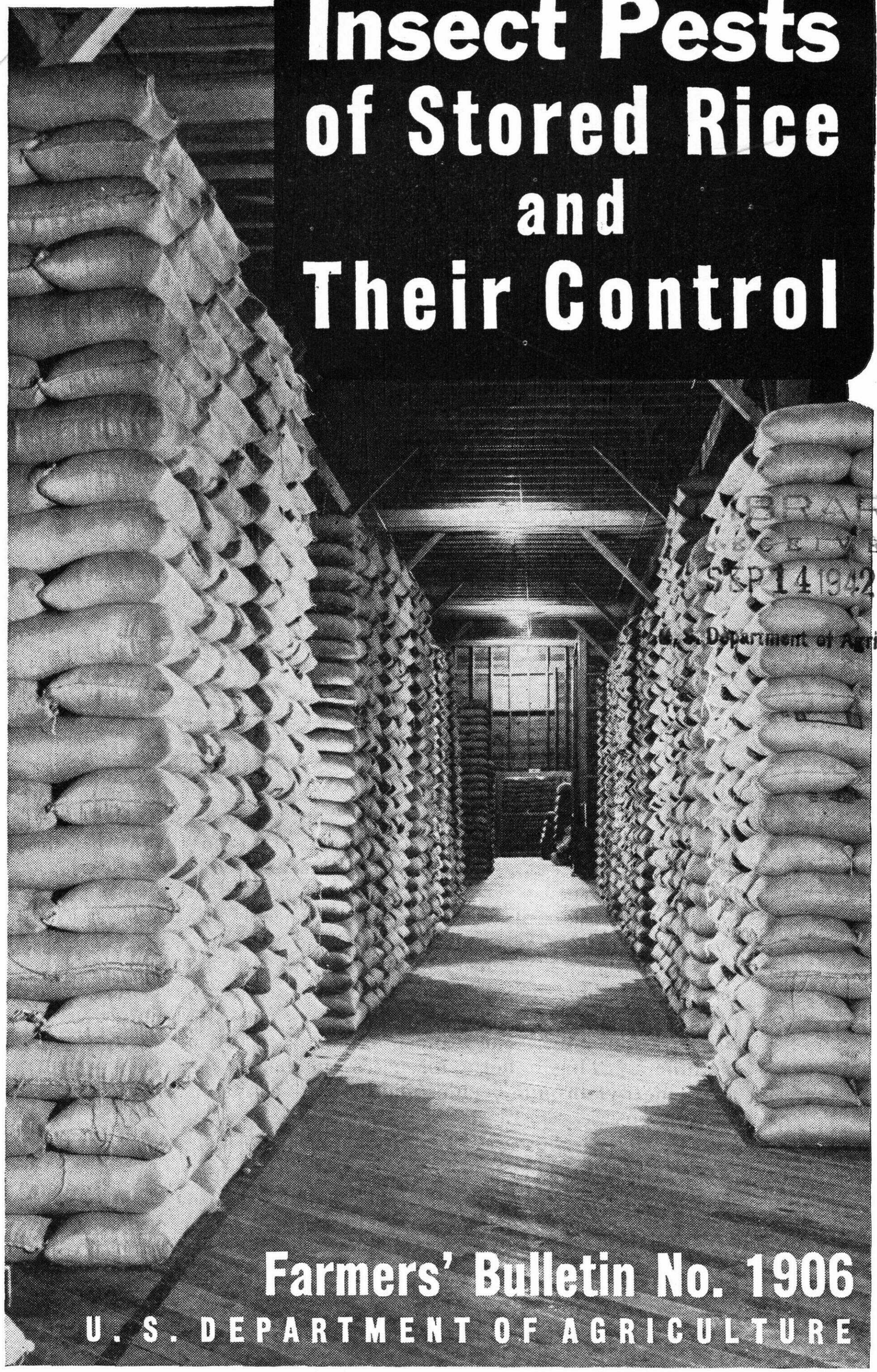
Insect Pests of Stored Rice and Their Control



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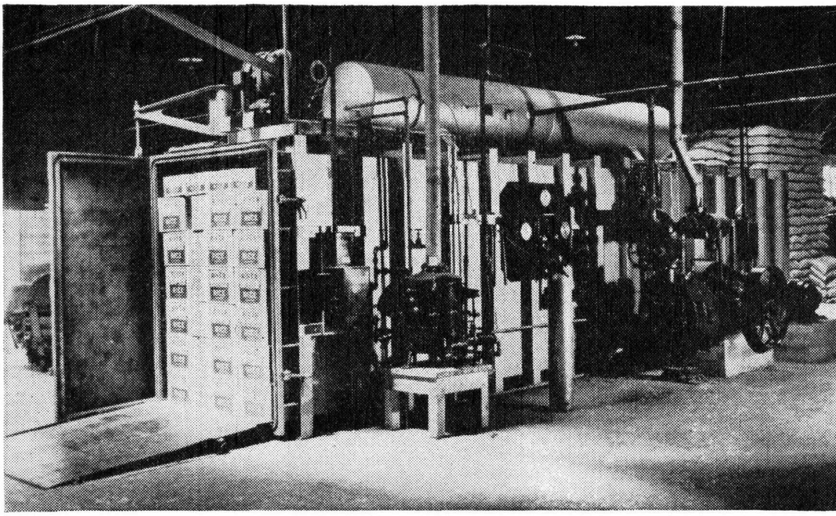

Rectangular vacuum vault loaded with rice ready for fumigation.

CLIMATIC CONDITIONS prevailing in the Gulf States and in California where rice is grown favor field infestation and the rapid increase of insect pests in the grain after it is placed in storage. If proper storage facilities are available, rough rice can be successfully fumigated, and these insects destroyed.

The protection of rice stocks from insect attack before and after milling is difficult unless the warehouses are of modern concrete or brick construction and suitable for periodic fumigation. Several fumigants are available, however, that can be relied upon for effective control when used in tight warehouses, in atmospheric vaults, or in vacuum chambers. This bulletin discusses the use of hydrocyanic acid, methyl bromide, chloropicrin, and ethylene oxide for this purpose.

Washington, D. C. Issued August 1942

INSECT PESTS OF STORED RICE AND THEIR CONTROL

By AUGUST I. BALZER, *assistant entomologist, Division of Cereal and Forage Insect Investigations, Bureau of Entomology and Plant Quarantine*

Contents

RICE is produced commercially on a large scale in the United States, principally in Louisiana, Texas, Arkansas, and California. The average crop for the United States is approximately 45 million bushels, or 12½ million barrels of 162 pounds each. The annual losses caused by insects that attack stored rice are estimated at $3,125,000, or 10 percent of the total value of the crop. This does not take into consideration any injury which the reputation of the milling company may suffer when its well-established brands of products are found to be contaminated by the presence of insects.

Two methods of handling and storing rough rice are practiced. In the more humid sections the rice is usually harvested when the moisture content of the grain is 18 to 22 percent. If the rice is harvested with a binder (fig. 1), the sheaves are shocked and allowed to dry until the grain contains approximately 14½ percent or less of moisture, when it is threshed from the shock and put in burlap sacks holding from 162 to 200 pounds each. The sacked rice is then stored in warehouses owned by individuals, growers' associations, or mills. In the more arid sections of the country the rough rice may be stored in bulk in large commercial or privately owned elevators or in farm bins. In these sections the crop may be harvested with either a combine harvester or a rice binder.

Warehouses used for storing sacked rough rice are generally of simple, loose construction, most of them being of the frame and sheet-metal type shown in figures 2 and 3. A few are provided with concrete floors, but the majority have wooden floors. The capacity of these warehouses ranges from a few thousand to more than one hundred thousand sacks. Most of the larger elevators used for storing bulk rice are of the crib type (fig. 4) that is difficult to keep free from insect infestation owing to the method of constructing the walls and bins.

The rough rice is sold to the miller, who may transfer it to the mill immediately or leave it in the producer's warehouse or elevator until he is ready to move it. The rice is milled as rapidly as practi-

FIGURE 1.—Harvesting rice with binders.

FIGURE 2.—Warehouse used for storing rough rice. This building is 300 feet long and 180 feet wide and has a storage capacity of 20 million pounds of sacked rough rice.

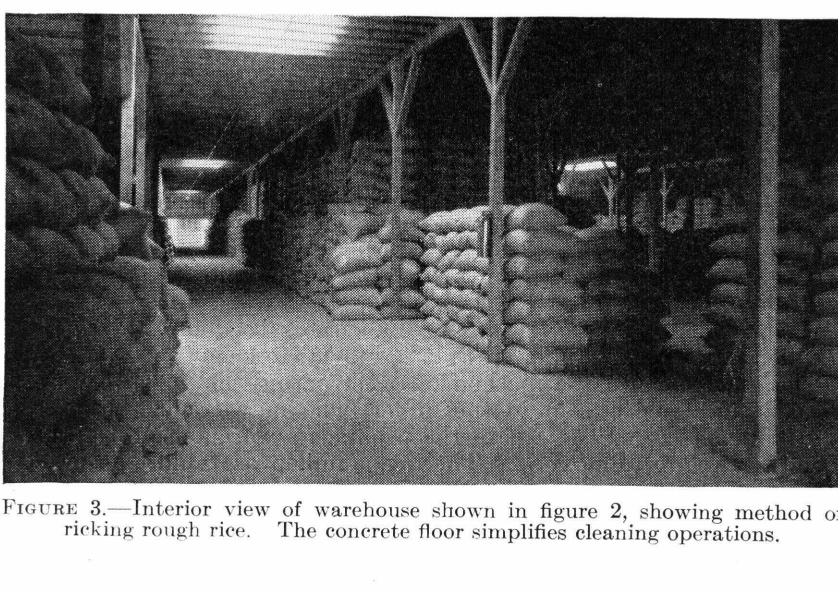

FIGURE 3.—Interior view of warehouse shown in figure 2, showing method of ricking rough rice. The concrete floor simplifies cleaning operations.

cable, and the milled rice is then stored in burlap sacks, commonly called pockets, each weighing 100 pounds. Practically all milled rice is stored in the mills in such pockets, and often it is reconditioned before it is shipped. The milled rice is sold in 100-pound burlap or cotton sacks, and sometimes in paper bags, which are enclosed in cotton bags. It also may be packaged in small cardboard boxes with or without cellophane windows, in heavy paper bags, or in cellophane bags. Most of the packaged rice is packed shortly before it is shipped, and is shipped in corrugated-paper cases.

Quite frequently stocks of both rough and milled rice are carried over into the new crop season. In 1939 there was a carry-over in the United States of approximately 1 million pockets of milled and 472,222 bushels of rough rice.

This bulletin contains information on the fumigation of rough rice (kernels enclosed by the hulls), brown rice (hulls removed from kernels), milled rice, screenings, and brewers' rice (broken rice, free from bran and embryo), and the bran and polish.

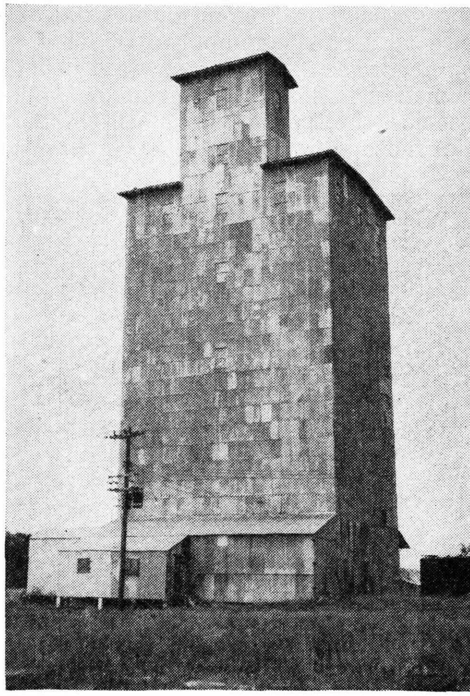

FIGURE 4.—Crib-type elevator sometimes used for storing rough rice.

The climatic conditions in much of the area in which the rice is produced and stored are highly favorable for the multiplication of insects. The warm season is long, the winters are mild, and conditions seldom become too dry in the Gulf region to interfere with insect activity. Most of the present warehouses and mills are not tight enough to permit successful mass fumigation with gas, nor are they equipped to store separately the infested and the uninfested rice. Most rice mills carry rough and milled rice in the same building, thus providing opportunity for the insects to migrate from one lot to the other. A few mills are equipped with atmospheric or vacuum vaults in which milled rice is fumigated just prior to being shipped.

Some 30 species of insects have been found infesting stored rice and rice products, but of these only a few are a serious menace to rice that is in good condition. Only the more important insects are considered in this bulletin. For brief accounts of the life histories and habits of the insects that infest stored grain, together with illustrations of the more destructive forms, the reader is referred to Farmers' Bulletin 1260, Stored-Grain Pests, issued by the United States Department of Agriculture.

INSECTS INFESTING ROUGH RICE

The Angoumois grain moth (*Sitotroga cerealella* (Oliv.)), the lesser grain borer (*Rhizopertha dominica* (F.)), and the rice weevil (*Sitophilus oryza* (L.)) are the most destructive insect pests of rough rice. These insects bore into the kernels, at times almost completely destroying them (fig. 5). The first two are capable of entering the grain through the hull, but the rice weevil attacks only grains of which the hulls have been broken or have failed to close properly after blooming. In addition to these there are several species that feed on the surface of the kernels, on broken grains, and on grains damaged by the boring insects. The commonest of these are the cadelle (*Tenebroides mauritanicus* (L.)), the saw-toothed grain beetle (*Oryzaephilus surinamensis* (L.)), the flat grain beetle (*Laemophloeus minutus* (Oliv.)), psocids, the Indian-meal moth (*Plodia interpunctella* (Hbn.)), and the rice moth (*Corcyra cephalonica* (Staint.)).

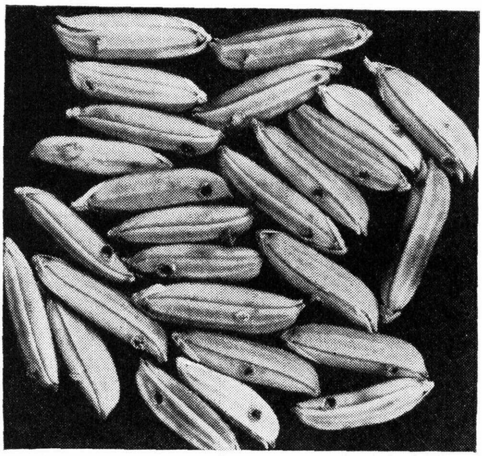

FIGURE 5.—Rough rice showing exit holes of the Angoumois grain moth.

A lot of rough rice placed in a poorly constructed warehouse in August 1938 was examined periodically during the summer of 1939 for loss in weight due to insect damage. Between June 29 and August 31 there was a loss in weight of 3.23 percent due to Angoumois grain moth infestation. In an experiment begun in November 1938 it was found that the loss in weight of rough rice of four commonly grown varieties due to insect attack while in storage was, by May 2, 1939, 2.2 percent, by July 31, 4 percent, and by November 21, 10.7 percent. These losses in weight were independent of changes in weight due to variations in the moisture content of the rice.

The damage caused by insects to the rice was due not only to the actual loss in weight but also to the smaller yield, when the rice is milled, of whole kernels or head rice, which was worth 3¼ cents per pound, while the broken grains brought only 2 cents. In the experiment just mentioned the total monetary loss had amounted to 35½ cents per barrel on July 31 and to 69½ cents per barrel on November 21. On these dates the rice had been stored approximately 9 and 12 months.

Rough rice stored in bulk sometimes suffers considerable damage from heating that may be partly attributed to the activities of insects. Active insects generate body heat and give off moisture, both of which are absorbed by the surrounding grain, thus producing hot spots. It was found that killing the insects by fumigation resulted in a return of the grain to normal temperatures unless other factors were involved in the heating. Conditions other than insect infestation may, of course, cause grain to heat.

INSECTS INFESTING MILLED RICE

After the hulls have been removed from the rice the situation is somewhat different, and some insects of minor consideration in rough rice become important. The main offenders in brown and milled rice, in screenings, and in brewers' rice are the saw-toothed grain beetle, the flour beetles *Tribolium castaneum* (Hbst.) and *T. confusum* Jacq.-Duv., the cadelle, the flat grain beetle, the Indian-meal moth, the rice moth, the corn sap beetle (*Carpophilus dimidiatus* (F.)), psocids, the lesser grain borer, and the rice weevil. Of these, only the rice weevil and the lesser grain borer bore into the kernels (figs. 6 and 7). The others feed externally, only damaging the surface of the kernel, but their presence and the fact that they injure the surface of the kernels make them not only very objectionable but costly to the industry. In brown rice the rice weevil is the major pest and frequently does much damage. Occasionally the lesser grain borer infests brown rice, especially when it is packaged in paper bags or cardboard cartons. Practically all rice pests prefer brown to milled rice.

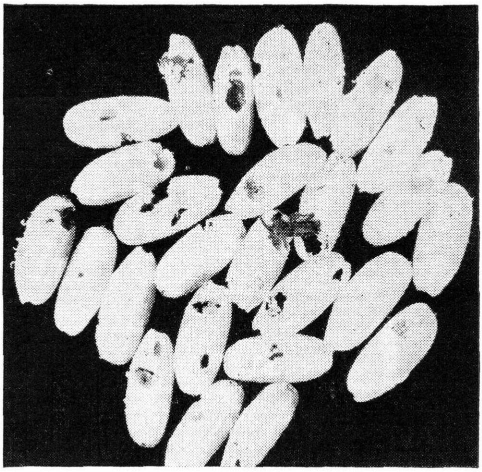

FIGURE 6.—Kernels of milled rice damaged by the rice weevil.

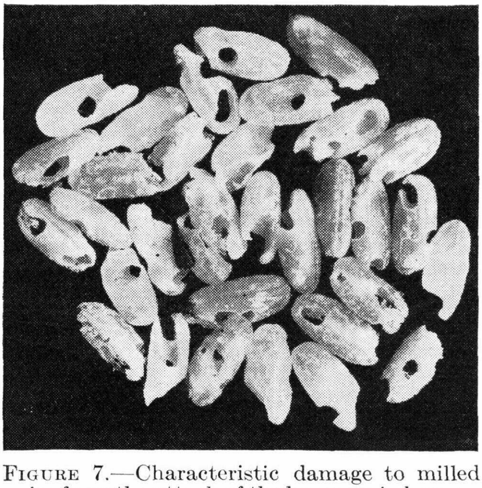

FIGURE 7.—Characteristic damage to milled rice from the attack of the lesser grain borer.

The larvae of the Indian-meal moth and the rice moth are particularly troublesome on account of their habit of spinning silken threads. The Indian-meal moth larva spins a web as it develops and leaves behind it a silken thread wherever it crawls, and when it pupates it attaches to the sack a silken cocoon, which is rather difficult to remove. The rice moth larva spins dense tubes, webbing the kernels into the walls of the tube. These webs are difficult to remove from the rice, and hence more or less rice is lost in the cleaning process.

The practice is to fumigate the rice and remove the dead insects just prior to shipping. Both these processes require costly equipment

and careful manipulation. Badly infested milled rice must sometimes be remilled to be restored to a satisfactory condition.

SOURCES OF INFESTATION

Rice may become infested with these insects before it leaves the field or while stored on the farm, in warehouses, in elevators, and in transit in boxcars or ships.

A number of the insect pests of stored rice can fly, and several species frequently attack rice in the field before it is harvested. This is particularly true in the sections where the crop is grown near farm buildings, granaries, fields of corn or sorghum, or stacks of old rice straw that are allowed to remain in the field until after the rice begins to mature. Because of the moderate winters in much of the rice-producing area, stored-grain insects often successfully overwinter in the grain remaining in strawstacks and in granaries. When warm weather arrives in the spring, these overwintered insects multiply rapidly, and some migrate to the new grain crops as they mature in the field. W. A. Douglas investigated the field infestation by insects injuring rice in storage. He reported[1] that a total of 369 insects emerged from 444 one-half pound samples of rough rice which he collected, during a 4-year period, from fields adjacent to rice warehouses, corn and sorghum fields, and woodland, and near old rice strawstacks. Samples were taken from shocked rice at a point in the field nearest the potential source of infestation, at points 50, 100, 200, and 400 feet from the source, and from a point approximately in the center of the field. Each sample consisted of rough rice, taken about 10 days after the rice was shocked, from 3 shocks at each location. Five species of insects were reared from the samples. Those found most frequently were the Angoumois grain moth, the rice weevil, and the flat grain beetle. The Angoumois grain moth ranks first in importance as an insect injurious to stored rough rice, and the rice weevil ranks second.

To reduce field infestation Douglas[1] recommended the following action: (1) Clean warehouses thoroughly and dispose of, fumigate, or burn all old grain, feed, and sweepings before the new crop of rice heads; (2) spread strawstacks on stubblefields, if possible, or burn them by the end of May after green pasturage is available for the cattle that have been feeding on them; and (3) avoid, if possible, planting corn or sorghum near rice fields.

Warehouses, elevators, and storehouses on the farm usually harbor insects from year to year in feed, old rice, sweepings, and grain that have lodged in or dropped through cracks and crevices in the floor and walls. When insects are present they almost immediately migrate to the new rice to start their destructive work, the resulting rate of infestation and damage depending on the insect population present in the storehouse when the new rice is moved in, the condition of the rice, and the prevailing temperatures.

Railway boxcars used to transport grain are likely to carry large numbers of grain insects concealed in cracks and crevices and breeding in accumulations of waste grain and milled products that have become lodged behind the car linings, particularly at the ends of the cars. Infestation of grain shipments is certain to take place in such cars. Infested grain arriving at a warehouse, elevator, or mill affords an

[1] W. A. DOUGLAS. FIELD INFESTATION BY INSECTS THAT INJURE RICE IN STORAGE. U. S. Dept. Agr. Cir. 602, 8 pp., illus. 1941.

opportunity for insects to spread to insect-free grain already in storage.

Stored-grain insects can and do enter warehouses and mills by flight. In an experiment conducted during the summer of 1937, nine species of stored-grain insects, including the worst enemies of milled and rough rice, were collected in insect flight traps at two rice mills.

Insects live and breed in the rice materials lodged in the milling machinery and infest the rice as it flows by and through the points of infestation. These deposits are important sources of infestation in milled rice. During May and June 1937 an average of 425 insects were found per 1-pint sample of material collected in elevator boots, conveyors, spouts, and milling units, in a survey of 4 rice mills along the Gulf coast that had been closed down at the end of the milling season. In these collections 23 species of stored-grain insects were identified, including all the important pests of stored rice.

CONTROL MEASURES

FUMIGATING ROUGH RICE IN BINS

Insects in rough rice stored in covered wooden cribbed bins can be satisfactorily fumigated with a crude granular calcium cyanide equivalent to 23 to 28 percent of available hydrocyanic acid. On exposure to air, the calcium cyanide reacts with the atmospheric moisture to form hydrocyanic acid. This treatment does not affect the germination or milling qualities of the grain, and after the grain is milled, no undesirable residue is left. Milled rice should not be fumigated with this chemical, however, as it is likely to produce a spotted product.

The fumigant is applied by feeding it into the center of the stream of rice in the spout, as the bin is being filled. Specially designed gravity feed devices that fit into the calcium cyanide containers are obtainable for this purpose. The devices are equipped with graduated dosage plugs so that the fumigant can be run into the grain stream at any desired rate. It was found that a dosage of 8 pounds of the crude commercial calcium cyanide per 100 barrels, or 360 bushels of rice, or 16 pounds per 1,000 cubic feet of space gave a satisfactory kill in covered wooden cribbed bins. The first 30 and last 30 barrels of rice run into the bin should be treated with a double dosage to compensate for any gas that may escape.

CAUTION.—Calcium cyanide should be handled with great care, as it is extremely poisonous to human beings as well as to insects. Operators handling calcium cyanide should wear an all-service gas mask at all times. They should stay out of the bin and away from the top of the bin unless it is completely enclosed and absolutely tight, since the air displaced by the rice carries some of the gas with it. In a bin having a tight top, the displaced air with the gas should be vented to the outside, where it cannot be harmful. All the bin-house windows should be kept open during the time of application. The bins should not be entered while under fumigation, nor should a bin from which the treated grain has recently been removed be entered without the protection of an AIR-LINE GAS MASK, SUPPLIED WITH AIR FROM A SAFE SOURCE. The person entering the bin should also have the entire skin area of his body protected. The bin should be

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thoroughly aerated, great care being taken that no pockets of gas remain, before anyone is permitted to enter the bin without a gas mask. Even with the protection of a gas mask, it is advisable not to stay in the concentration very long, as the hydrocyanic acid gas is capable of entering the body through the skin, especially when one is perspiring freely.

For a more complete discussion on the subject of controlling insect pests of grain in elevator storage, the reader is referred to Farmers' Bulletin 1880, Control of Insect Pests of Grain in Elevator Storage, issued by the United States Department of Agriculture.

MILL AND WAREHOUSE SANITATION

In order to restrict infestation in the warehouse, elevator, mill, or storehouse to a minimum, it is important to keep the buildings

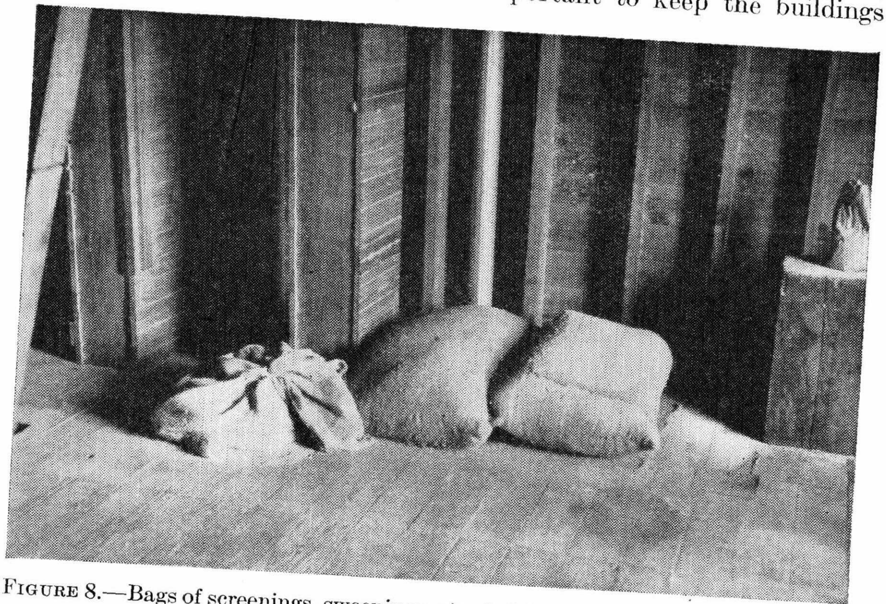

FIGURE 8.—Bags of screenings, sweepings, etc., left in the mill harbor many insects.

clean. The illustration on the cover page shows a well-kept storage house. Grain, feed, and deposits of floury material harboring insects should not be allowed to accumulate on the floor, under or near the building, or in the machinery (fig. 8). As far as possible, the machinery should be arranged so that it can be readily cleaned. The building should be constructed so as to avoid the possibility of damp, dark places. Floors, walls, and ceilings should be smooth, to eliminate hiding places and facilitate cleaning. Insects removed in the process of cleaning or milling the rice should be destroyed by burning or by treating the accumulations in which they occur with heat or fumigants.

TREATMENT OF TAILINGS FROM CLEANING MACHINERY

Tailings from rice-cleaning machinery usually contain many insects that, unless properly disposed of, are likely to spread to stocks of

uninfested rice in the mill. In many cases the tailings are caught in burlap sacks that, when filled, are set aside for an indefinite period without treatment. To avoid infestation from this source, a satisfactory method has been devised for collecting the tailings in a tight metal container (fig. 9) which should be large enough to hold a day's run of tailings. To prevent the escape of insects from such a container while it is being filled, arrangement can be made for the tailings to fall into the container through a metal funnel heated by means of an infrared lamp. The insects will thus be prevented from climbing up the heated sides of the funnel and escaping. The tailings can be treated over night in the container with a mixture composed of 75 percent of ethylene dichloride and 25 percent of carbon tetrachloride at the rate of about 1½ ounces of the mixture per 100 pounds of tailings, or the tailings may be removed from the container and fumigated immediately. If the tailings are treated in the container in which they are collected, mills operating on a 24-hour basis should have two of these containers, to be treated alternately.

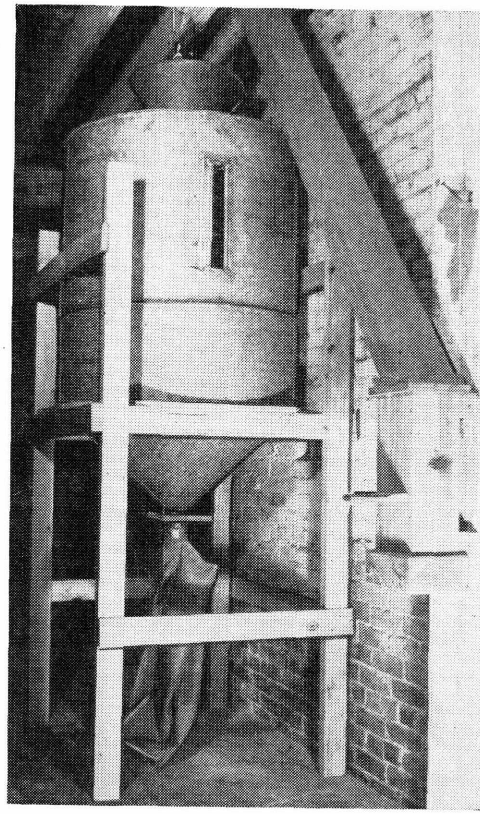

FIGURE 9.—Metal container used for collecting tailings from rice-cleaning machinery. The tailings fall into the container through a funnel which is heated by an infrared-ray lamp to prevent the escape of insects. After the container is filled, it is fumigated to kill the insects in the tailings, or the tailings may be removed and fumigated. A glass window has been inserted in the container to show when it is full.

Insect infestation in tailings can also be destroyed satisfactorily with heat produced by infrared rays as the tailings come from the cleaning machinery. The apparatus shown in figure 10 consists of a slightly inclined metal trough over which are suspended several infrared lamps. The tailings in the metal trough are moved forward slowly under the lamps by means of an eccentric or vibrator. The number of lamps required and the size of the metal trough will depend on the quantity of tailings to be treated and the temperature of the tailings on leaving the cleaning machinery.

With a few adjustments the apparatus can be adapted to suit any individual situation and can be operated at a comparatively low cost. It is essential that the tailings pass under the lamps in a thin layer.

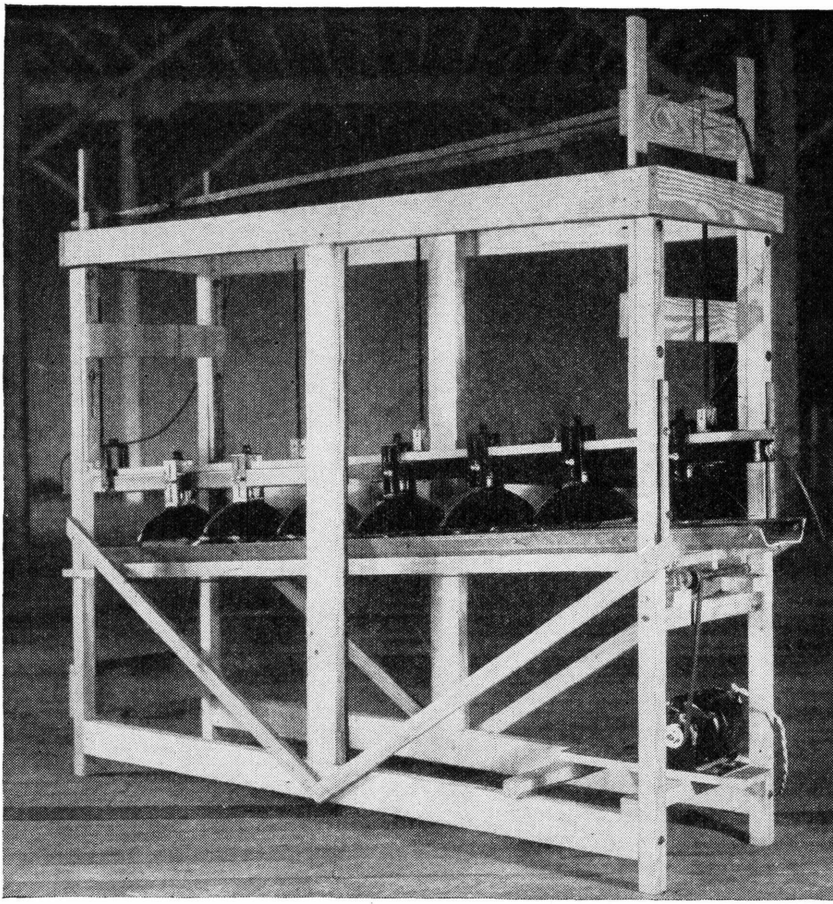

FIGURE 10.—Apparatus for killing insects in rice tailings with heat from infrared rays. This machine equipped with a 5- by 82-inch insulated galvanized sheet-iron grain trough, seven 250-watt infrared-ray lamps and gold-plated adjustable reflectors satisfactorily treats tailings at 87° F. at the rate of 105–120 pounds per hour.

HEATING AND DRYING

Insects infesting stored grain are largely dependent on the moisture in the grain for their life processes. Some species are able to subsist on drier food than others. Most of the insects infesting stored rice prefer grain having a relatively high moisture content. Wheat grown in the Pacific Northwest is usually harvested with a moisture content of 8 or 9 percent and is singularly free from insect damage. Rice stored in the Southern States, however, is seldom if ever too dry to sustain insect life.

The drying of moist rice and rice byproducts reduces their susceptibility to insect damage, and exposure of the grain to high temperatures kills the insects. An exposure of 10 minutes to a temperature of 140° F. is fatal to all insects infesting stored rice. Several problems are involved, however, in subjecting rice to heat. The rice heats

so slowly that the insects are protected by the grain itself. In experimenting with a commercial drier using hot-air blasts the author was unable to obtain a satisfactory kill of insects in rough rice with air blasts at 140° for 30 minutes. This treatment raised the temperature of the rice to only 122°, which was not high enough to kill the insects. Furthermore, heating for insect control is not favored by the rice industry owing to the danger of causing the rice to check and because of the removal of too much moisture.

FUMIGANTS AND PRECAUTIONS IN THEIR USE

Prompt and timely fumigation offers the solution of many of the insect problems of the rice miller and producer. A number of excellent fumigants are available that are both effective and reasonable in cost, and although complete information as to dosages under all conditions is not at present available, a wealth of knowledge has been accumulated regarding the common fumigants. The following pages contain a discussion of the methods recommended for fumigating mills, warehouses, and elevators as a whole, and for the fumigation of individual lots of rice and rice products in bins, in gastight vaults at atmospheric pressure, and in vacuum chambers.

DANGER FROM FUMIGANTS—Fumigants toxic to insects are also toxic to human beings. It is therefore necessary that the persons handling them avoid exposure to dangerous concentrations of the gases. Operators should be thoroughly acquainted with the fumigant with which they are to work, and should take all necessary precautions in conducting the fumigation. Unless the operator is acquainted with the fumigant and methods of using it, it is preferable before undertaking fumigation work to have a professional or experienced fumigator instruct the workmen who are responsible for its use, or, in large operations, to have it done by professional fumigators.

Gas masks equipped with canisters of the proper type for protection against the particular fumigant being used can be relied upon for complete protection only against low concentrations encountered around the equipment being used and the outside of bins. They are not to be used in the bins or in other high concentrations of the gas. Not all commercial canisters have a time guarantee. Even where used in light concentrations, a canister should not be used for more than 1 hour, after which it should be replaced by a fresh, unused canister. The only complete protection from high concentrations is to use an air-line mask supplied with air from a safe source and have the entire skin area protected.

WAREHOUSE FUMIGATION

The fumigation of entire warehouses filled with pockets of milled rice is being practiced successfully in buildings that are or can be made gastight. Efficient fumigation arrests the insect infestation and damage until the plant becomes reinfested from outside sources. Usually only one or two treatments a year are necessary to keep the contents of a tight warehouse reasonably free from insect damage. The number of fumigations required depends on the quantity and condition of the rice carried over from one season to the next, entry of insects from outside sources, and the effectiveness of the first treat-

ment. Ordinarily if new-crop rice is stored in a clean warehouse, one fumigation about midsummer is sufficient, provided there is no reinfestation from outside sources. If rice is carried over from one season to the next, however, or if insects from outside sources fly into or otherwise enter the warehouse, an early summer and a fall fumigation are sometimes necessary. A second fumigation also becomes necessary when the first proves unsuccessful. For warehouse fumigation both hydrocyanic acid and methyl bromide are effective.

Preparation of Building for Fumigation

All polish, bran, sweepings, and other materials that harbor insect pests and are difficult to penetrate with the fumigant used should be treated separately in an atmospheric vault or vacuum chamber when preparation is being made for mass fumigation of milled rice in pockets. Where this is not feasible, the dosage of fumigant should be increased to take care of the situation. All windows, doors, ventilators, eaves, and other openings in the building should be closed and carefully sealed with heavy paper and paste, or with putty. This is essential; otherwise the gas will escape, thereby preventing the building-up of a concentration fatal to insect life.

Liquid Hydrocyanic Acid for Warehouse Fumigation

Hydrocyanic acid is a satisfactory fumigant for milled rice stored in pockets in a reasonably tight building or for rough rice in bags. Although this gas can be produced in several ways, only the liquid method will be discussed, as this has been used almost exclusively for the fumigation of rice in warehouses. Liquid hydrocyanic acid (96–98 percent HCN) is a volatile, colorless liquid boiling at 77° F. It evaporates to form a gas, the specific gravity of which is 0.93 as compared with air. It is marketed in cylinders containing 30 and 75 pounds of liquid. **Hydrocyanic acid is extremely poisonous to human beings**, although it can be safely used if properly handled. This fumigant does not injure the quality or color of the rice.

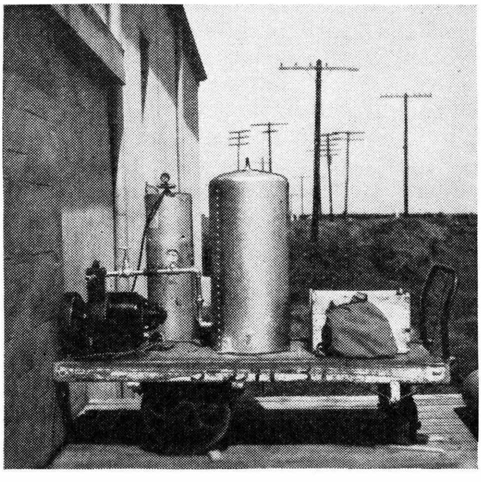

FIGURE 11.—Cylinder of liquid hydrocyanic acid and air compressor placed in readiness to fumigate a rice warehouse.

Liquid hydrocyanic acid is usually applied through a piping system of ⅜-inch (outside diameter) soft, seamless copper tubing installed throughout the building. Disk-type spray nozzles, so spaced as to insure uniform distribution of the gas, should be provided, one for each 10,000 to 15,000 cubic feet of space. Special pressure-type nozzles now on the market are fitted with a device to prevent clogging and need not be removed for cleaning. The inlets to the

piping system, one for each floor, are at convenient points outside the building, usually on the loading platform (fig. 11). The cylinders of hydrocyanic acid are connected to the piping inlets by means of short lengths of special rubber hose, or, if desired, a manifold arrangement may be used. The liquid is forced into the warehouse by means of air pressure applied to the cylinders. For detailed instructions on the fumigation of buildings with liquid hydrocyanic acid the reader is referred to United States Department of Agriculture Circular 369, Industrial Fumigation Against Insects.

A dosage of 16 to 24 ounces of liquid hydrocyanic acid per 1,000 cubic feet of space is recommended. The exact dosage required will depend upon the quantity of rice in the building—the larger the quantity, the higher the dosage should be. Both rice bran and polish require a considerably higher dosage than the rice itself.

An exposure of 72 hours should be allowed, after which the building may be opened for aeration. **A gas mask should be worn by the operator while he is opening the building.**

Methyl Bromide For Warehouse Fumigation

Methyl bromide is a recently developed fumigant found to be well adapted for treating rough or milled rice stored in bags in tight brick or concrete warehouses. This fumigant is a colorless liquid which boils at 40.1° F., thus making it effective for fumigating at reasonably low temperatures. The specific gravity of the liquid is 1.732 at 32°. At ordinary temperatures, when not confined under pressure in containers, it is a gas. It is noninflammable and stable, has a low water solubility, has remarkable powers of penetration, and is relatively inexpensive. In low concentrations methyl bromide does not have a distinctive odor, but in high concentrations a sweetish odor approaching that of chloroform may be perceived. **The comparative lack of odor is a disadvantage in that it does not warn the workmen of their danger when working in concentrations that are low and yet toxic to human beings. With an intelligent understanding of the hazard and the use of proper precautions, as subsequently described, methyl bromide may be used without harmful effects to workmen.**

Methyl bromide is obtainable in liquid form under low pressure in cylinders containing 10, 50, or 150 pounds net, or in 1-pound cans. The pressure within the cylinders, due to the vapor pressure of the methyl bromide, will vary with the temperature. At high temperatures it is sufficient to eject the liquid forcibly from the cylinder when the valve is opened, whereas at 40° F. the pressure gage reads 0. To facilitate its use at all temperatures, therefore, the pressure normally occurring within the cylinder is increased by charging it with sufficient air at the time of shipment to eject all the liquid forcibly, even at temperatures below 40°.

The cylinders are equipped with siphon tubes extending to the bottom so that the pressure will cause the liquid to issue from the exit port at the top when the valve is opened, without the necessity of inverting the cylinder.

Methyl bromide may be applied in several ways for the fumigation of rice in warehouses. It is usually applied by placing a number of 10- or 50-pound cylinders in the warehouse so as to insure a uniform distribution of the gas. The fumigant is released above the rice ricks or near the ceiling through a length of ¼-inch (outside diameter) cop-

per tubing connected to the exit port of each cylinder, the open end of the tube being pinched shut and two ⅛-inch holes bored through the tube near the closed end so that the liquid is ejected horizontally in opposite directions above the rice (fig. 12).

The men who release the fumigant must wear gas masks equipped with canisters that will give protection from methyl bromide, and they should begin first with the cylinders farthest from the exit, opening each valve completely and working toward the door. The door left unfastened for exit should be sealed immediately after the persons releasing the gas have left the building. The liquid evaporates as soon as it is released. Circulating fans should be operated inside the warehouse during the period of fumigation to facilitate the distribution of the gas. If desirable, the methyl bromide can be applied from the outside through a piping system similar to that described for the use of liquid hydrocyanic acid. When this latter method of fumigation is used, the pressure in the cylinder should be increased to 150 pounds by charging it with compressed air to insure the complete ejection of the methyl bromide. In cool weather the pressure in the cylinder may have to be renewed in order to empty it quickly.

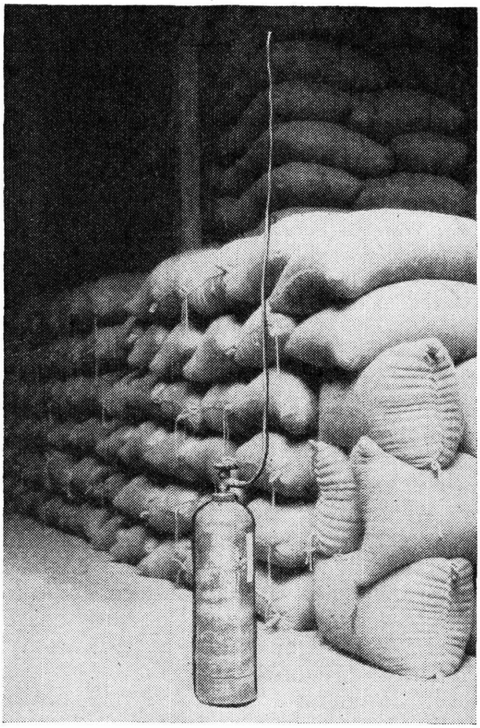

Figure 12.—Methyl bromide cylinder with copper tubing attached so as to release gas near ceiling of warehouse.

A dosage of 1 pound for milled rice and 1¼ pounds for rough rice, per thousand cubic feet of space is recommended for a satisfactory insect kill. An exposure of 16 to 24 hours should be allowed, and after this the building can be opened for aeration. The workmen opening the building should wear gas masks. Ordinarily it requires from 4 to 8 hours to aerate so completely a building fumigated with methyl bromide that it may be entered safely without a gas mask. The speed of ventilation will, of course, depend upon the number of windows and doors opened and the draft of air through the building.

It is suggested that persons interested in using methyl bromide obtain from the United States Public Health Service copies of the poster, published May 16, 1938, entitled "Preliminary Recommendations to Fumigators Using Methyl Bromide or Mixtures Containing Methyl Bromide as a Fumigant." This publication states, in part, that, "**While methyl bromide is less toxic to man than certain other fumigants, * * * all persons entering fumigated rooms, cars,**

or sheds to open ventilators or to unload fumigated materials, should observe precautions used with other toxic fumigating gases. * * * Experience indicates that adequate precaution will obviate danger of injury by this gas."

ATMOSPHERIC-VAULT FUMIGATION OF MILLED RICE

Small lots of rice or rice products are economically treated in a gastight room of suitable size, commonly known as an atmospheric fumigation vault or chamber, because the treatment is made at atmospheric pressures. Such a fumigation chamber may be constructed of any material that can be made gastight. A very satisfac-

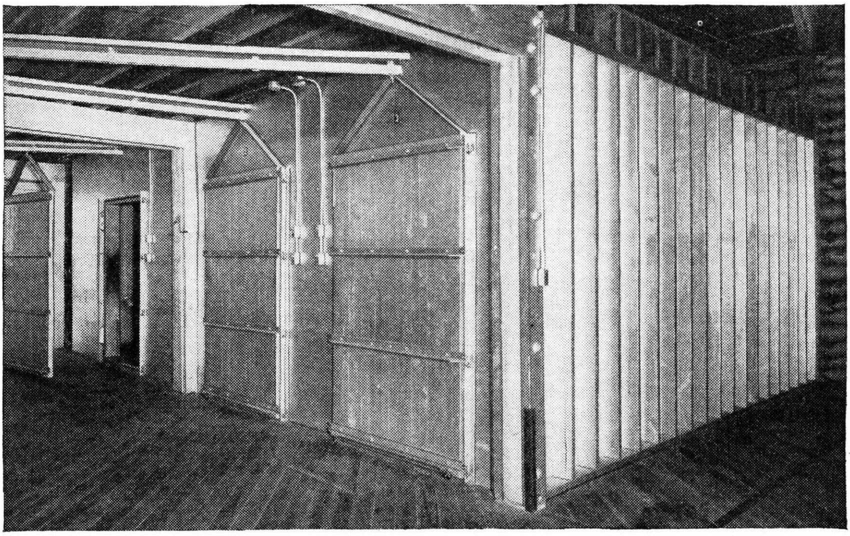

FIGURE 13.—A battery of three atmospheric vaults of frame construction lined with 24-gage galvanized sheet metal. These vaults have a combined capacity of 2,000 pockets of milled rice. One discharge blower is used to ventilate all three vaults. Note the convenient arrangement by which the doors are swung out of the way during the loading or unloading of the vaults.

tory, inexpensive vault (fig. 13) can be constructed of wood and lined with 24-gage galvanized sheet metal. The joints in the metal lining may be soldered or welded, or they can be tightened satisfactorily by overlapping the metal sheets approximately 1 inch, placing a narrow strip of builder's felt impregnated with asphalt between the overlapping metal, and nailing, or preferably screwing, a 1-inch half-round moulding over the joint to tighten it further. Other joints can be tightened in a similar way, as many layers of felt and asphalt being used as are necessary. Any other nails or screws driven through the metal should be applied only with the protection of half-round moulding, over builder's felt that has been impregnated with asphalt. This construction is to insure against leakage, which must be completely prevented if fumigation is to be economical and successful.

Suitable doors, complete with frame and rubber gasket, may be purchased already assembled, or a tight door can be constructed on the lid principle, the flat surface of the door being turned toward the door frame of the chamber. A rubber gasket attached to the door frame on the chamber makes a tight seal. The door should be fastened in place by means of bolts extending through it from the casing on all four sides. Hinged doors are hard to fasten tightly unless the hinges have loose joints which allow the door to be drawn up against the casing by means of bolts.

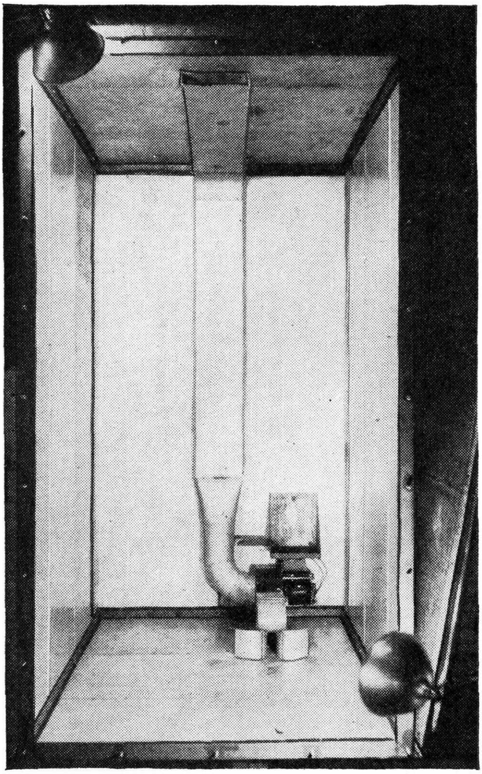

FIGURE 14.—View of interior of small vault, showing blower used to circulate the fumigant or to eject it from the vault.

A fan blower can be used satisfactorily for circulating the gas within the vault during the treatment and also to eject the gas afterward (fig. 14). The size of the blower to be used will depend on the size of the chamber. It should be large enough to change the gas in the chamber twice per minute. The blower may be mounted on either the inside or outside of the chamber, depending on the kind of gas that is used. If a corrosive or inflammable fumigant is to be used, the fan should be mounted on the outside. If the blower also is mounted on the outside, the blower case should be made gastight with a gasket in the exhaust-pipe joint and with packing around the fan shaft. The exhaust pipe should carry the gas outdoors to a point where there is no danger to people.

The rice is usually cleaned and resacked after fumigation in order to remove dead insects. In handling the fumigated rice a ventilating hood equipped with a suction fan should be placed over the hopper, as shown near the top of figure 15, to carry off any fumes released from the rice and to insure the comfort and safety of the workmen.

Methyl Bromide for Atmospheric-Vault Fumigation

Methyl bromide has been found to be a highly effective and comparatively inexpensive fumigant for the treatment of milled rice and rice products. In atmospheric-chamber fumigation methyl bromide is introduced from the outside through the wall by means of a ¼-inch (outside diameter) copper tube. The fumigant should be caught and allowed to evaporate in a metal pan fastened to the inner wall under

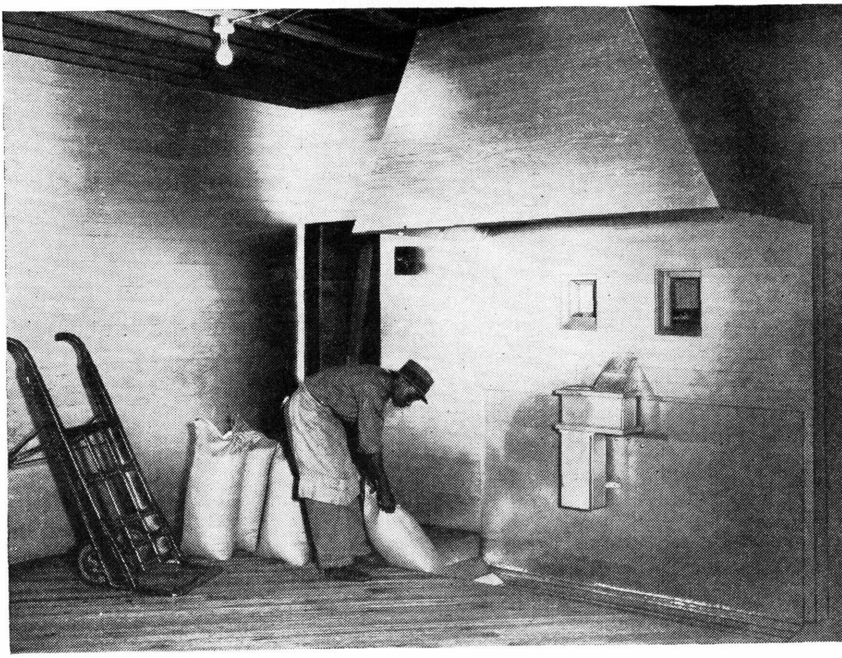

FIGURE 15.—Mixing-hopper room in rice mill showing, near top of picture, the ventilating hood over the hopper into which the fumigated grain is being dumped.

the inlet tube near the top of the chamber. The dosage and exposure time used will depend on the type of container in which the rice is to be packaged, the time available for fumigation, the temperature, and the quantity of rice contained in the vault. The dosages shown in table 1 have given satisfactory results for the fumigation of milled and brewers' rice at 70° F. and over, in a gastight chamber equipped with a circulating system operated in each instance for the first 4 hours. The dosage and the exposure period must be increased when rice is being fumigated at lower temperatures.

TABLE 1.—*Dosages of methyl bromide giving satisfactory results in the atmospheric-vault fumigation of milled rice at 70° F. and over*

Type of package	Exposure period	Dosage per thousand pounds of rice	Minimum dosage per thousand cubic feet [1]
	Hours	*Ounces*	*Pounds*
Burlap or cotton bag	4	1½	1¾
Do	6	1	1½
Do	12	½	¾
Cellophane bag or carton bag	15	1¼	1¾

[1] Do not use less regardless of size of load.

After fumigation the treated rice, still in the chamber, should be aerated. This requires approximately 1 hour, depending on the size of the exhaust fan. The gas having been expelled in this way, the workmen may safely handle the rice without wearing gas masks.

In ventilating the chamber it is important to see that treated rice is not reinfested by insects being drawn into the chamber by the draft caused while ejecting the gas. This can be avoided by having the fresh-air intake properly screened.

Liquid Hydrocyanic Acid for Atmospheric-Vault Fumigation

Excellent results in the fumigation of bagged milled rice in atmospheric vaults can also be obtained with liquid hydrocyanic acid gas. Dosages of 1½ ounces per thousand pounds of rice, or 2½ pounds per thousand cubic feet of space, for a 4-hour exposure, and 1 ounce per thousand pounds of rice or 1½ pounds per thousand cubic feet of space for a 15-hour exposure, were found satisfactory when the temperature of the rice was 80° F. or above.

The fumigant is introduced into the vault through a short piping system. In all cases the fumigant should be circulated in the vault during the exposure by means of a fan.

Chloropicrin for Atmospheric-Vault Fumigation

Chloropicrin is used to some extent in the fumigation of milled rice in atmospheric vaults. This fumigant is a colorless or slightly yellowish liquid a little more than 1½ times as heavy as water. It has a boiling point of 233.6° F., and on exposure to air it evaporates slowly, forming a vapor heavier than air. **The gas is nonexplosive and noninflammable as ordinarily used, is extremely toxic to insects and to man, and has a very irritating effect on the eyes and respiratory passages.**

Rice readily absorbs chloropicrin gas and afterwards liberates it slowly. In some systems of handling treated rice this slow liberation of the gas is a desirable feature in that it prevents immediate reinfestation by insects. Chloropicrin does not affect the color or quality of the rice.

Chloropicrin is marketed in 1-pound glass bottles and in cylinders containing from 1 to 100 pounds net. The larger cylinders are so arranged that a faucet valve can be attached and the liquid drawn off in any quantity desired. In the fumigation of milled rice in an atmospheric chamber the chloropicrin is introduced from the top of the vault through the roof by means of a ¾-inch pipe, at a point near or at the center of the ceiling. A shallow pan should be suspended under the inlet pipe to hold the fumigant until it has evaporated. A burlap sack placed in the pan facilitates the process of evaporation.

A dosage of 1 ounce per thousand pounds of head rice in cotton or burlap bags in a fully loaded chamber, or 1¾ pounds per thousand cubic feet of space, was found to give satisfactory results, with a 24-hour exposure and with the temperature of the rice at 75° F. and over. Sufficient data are not available at this time to permit recommendation of dosages for rice packaged in cellophane bags, or in cartons, or when the gas is circulated. Indications are that the dosage will have to be increased considerably when the rice is being fumigated in such containers. Circulation of the gas should increase the efficiency of the fumigation. The same precautions should be taken by operators applying chloropicrin as has been recommended for hydrocyanic acid gas, pages 7, 8, and 11.

VACUUM FUMIGATION

In vacuum fumigation the rice is placed in a steel chamber from which a large proportion of the air is subsequently evacuated by a pump and then is replaced with a fumigant (see inside front cover). By this method the gas penetrates the rice with much greater rapidity than in atmospheric fumigation. This permits shorter exposures than at atmospheric pressure, especially when tightly packed materials are being treated.

Vacuum fumigation chambers are made in many sizes, the larger ones being capable of holding one or more carloads. Both cylindrical and rectangular chambers are available.

The exhaust pump should be capable of drawing a 28-inch vacuum in 10 minutes. Multiple orifices for releasing the fumigant into the chamber and a circulation system for stirring the gas immediately after it has been injected facilitate the fumigation and reduce by 25 percent the dosage required. The use of a volatilizer, heated by steam, to vaporize the fumigant as it is being injected into the chamber also increases the efficiency of gases having a relatively high boiling point. Some vacuum chambers are equipped with an accumulator tank for heating and vaporizing the fumigant before it is drawn into the vacuum vault. At the end of the period of exposure the chamber is aerated by pumping the fumigant out of the tank and breaking the vacuum with air. Usually the fumigated products are "air-washed" several times by alternately drawing and breaking a vacuum of about 28 inches. Another very satisfactory method of ventilating the vacuum chamber is by the use of a discharge blower, or exhaust fan. In this method the vacuum is broken at the end of the exposure; and, as normal atmospheric pressure is approached, the discharge blower is started, and the chamber door from which the unloading is to begin is opened. This method is more rapid than that of breaking and pumping several vacuums and makes it unnecessary to operate the exhaust pump. **The discharge fan should be operated while the workmen unload the fumigated products.** As in the case of atmospheric vaults, the exhaust pipe should carry the gas to a safe point outside the building.

Liquid Hydrocyanic Acid for Vacuum Fumigation

Liquid hydrocyanic acid is highly satisfactory for the vacuum fumigation of milled rice and rice products. For maximum efficiency the hydrocyanic acid should be let into the vacuum chamber in the gaseous form. This is accomplished by drawing the liquid from the cylinder through a volatilizer.

Rice readily absorbs hydrocyanic acid and very slowly liberates it on exposure to the air—a feature that is of considerable advantage, since the insecticidal effect persists for some time after the rice has been removed from the vault. Unless fumigated rice is stored in a tightly closed room the slowly liberated gas is not likely to accumulate in quantities dangerous to any person. Treated rice can be run through an aspirator immediately after the fumigation and still retain enough gas after it is resacked to be lethal to insects—an effect known as postfumigation.

The dose for vacuum treatment of rice with hydrocyanic acid depends on the type of chamber, the length of exposure, and the tem-

perature of the rice. For treating rice at 60° F. or above, in a chamber in which the gas is introduced through one orifice and is not circulated, a dosage of 1¼ ounces per thousand pounds of rice, and never less than a minimum of 1¾ pounds per thousand cubic feet of space, has been found satisfactory at a 3-hour exposure for rice in burlap and cotton pockets, cellophane bags, and cartons of all types. In a chamber into which the fumigant is introduced through multiple orifices and is recirculated for 15 minutes immediately after it is introduced, the dosage can be reduced by approximately 25 percent without loss of efficiency.

After the fumigation the chamber should be air-washed twice before the workmen are allowed to enter to handle the treated products. When a strong discharge blower is used, it may be safe to enter the vault after 5 minutes of aeration. The fan should be operated during the entire time the rice is being unloaded, except when plenty of time has been allowed for aeration.

Methyl Bromide for Vacuum Fumigation

The low boiling point of methyl bromide makes it unnecessary under ordinary conditions to volatilize the liquid artificially before it is introduced into the vacuum chamber. The dosage required depends on the temperature, the length of the exposure period, the type of container in which the rice is packaged, and whether the gas is circulated in the chamber. For treating rice at 65° F. or above, in a chamber equipped with multiple gas inlets, and with circulation of the fumigant for 15 minutes, the dosages shown in table 2 have been found to give satisfactory results.

The same precautions are recommended for operators applying methyl bromide as for hydrocyanic acid gas, pages 7, 8, and 11.

TABLE 2.—*Dosages of methyl bromide required under various conditions for fumigating rice in a vacuum chamber*

Type of package	Exposure	Dosage per thousand pounds of rice	Minimum dosage per thousand cubic feet of space [1]
	Hours	*Ounces*	*Pounds*
Pocket	2	1½	3
Do	3	¾	2
Do	12	½	1
Cellophane bag or carton	2	2	4¼
Do	3	1½	3
Do	12	1¼	2½

[1] Use no less regardless of size of load.

After the fumigation, the rice is aerated by the same methods as described for vacuum fumigation with hydrocyanic acid. The necessary precautions given on pages 13, 14, and 15 for safely handling methyl bromide should be observed.

Ethylene Oxide for Vacuum Fumigation

Ethylene oxide in combination with carbon dioxide is another excellent gas for the fumigation of rice in vacuum. It is safe to handle, does not affect the quality of the fumigated product, and leaves no obnoxious odor.

Ethylene oxide is a colorless gas at ordinary temperatures but becomes a colorless liquid at 51.2° F. Its specific gravity is 0.887 at 44.6° to 39.2°. Ethylene oxide at concentrations of 3½ pounds or less per thousand cubic feet of space is noninflammable and nonexplosive, but it is inflammable at higher concentrations. It is not highly toxic to man, but like all fumigants **it is dangerous in heavy concentrations, and the operator should avoid exposure to the fumes unless he wears a gas mask.** It has been found that by mixing it with carbon dioxide in certain proportions the fire hazard is removed and its toxicity to insects increased.

A mixture of 1 part by weight of ethylene oxide with 9 parts by weight of carbon dioxide is commercially obtainable in steel cylinders equipped with a siphon tube extending to the bottom. This mixed gas is ejected by its own pressure, thus eliminating the necessity of inverting the cylinder. It requires preheating and volatilization before release into the chamber. The usual method of introduction is to draw a precalculated dose of the liquid from the cylinder into an accumulator tank, heat it to 120° F., then draw the gas into the fumigation chamber at a residual pressure of approximately 1 inch of mercury in the pressure gage (equivalent to a lowering of the mercury column approximately 29 inches at sea level).

For treating bagged rice at 65° F. a dosage of 1.33 pounds of fumigant to 1,000 pounds of material, with a minimum of 15 pounds to 1,000 cubic feet of space, in a vault having multiple gas inlets, and with the gas circulated for 15 minutes, has given a complete kill of insects in a 1-hour exposure. For a 3-hour exposure a dosage of 0.67 pound per thousand pounds of rice, with a minimum of 7 pounds per thousand cubic feet of space, is satisfactory. Rice at lower temperatures or rice when packed in cellophane bags or paper cartons requires a slightly larger dosage. The above dosages should be increased by 25 percent when the gas is released into the vacuum vault through only one orifice and is not circulated.

When rice is vacuum treated with an ethylene oxide-carbon dioxide mixture, only one air-washing after the fumigation is necessary to make it safe to enter or unload the vault. This fumigant dissipates readily from the fumigated products on exposure to air; consequently there is little postfumigation effect, and the treated product may become reinfested immediately after fumigation if exposed to insects.

FUMIGATION OF RICE IN RAILWAY BOXCARS

Both rough and milled rice can be successfully fumigated in all-steel grain boxcars that are tight and that have been properly sealed. If possible the cars should be prepared for fumigation before they are loaded, one door and all cracks being sealed from the inside. The sealing can be accomplished with paste and paper, gummed tape, or a putty composed of a mixture of rice polish or flour and oil.

The dosage and the exposure period will depend on the fumigant used, the time available for fumigation, the quantity of rice in the car, and the temperature. Methyl bromide, hydrocyanic acid, or chloropicrin can be used for the purpose.

ALL FUMIGATED CARS SHOULD BE PLACARDED ON BOTH SIDE DOORS AND ALL OTHER OPENINGS WITH A RED CARD SHOWING THAT THE CAR HAS BEEN FUMIGATED, GIVING THE DATE, NAMING THE FUMIGANT USED, AND WARNING EVERYONE NOT TO ENTER.

If methyl bromide is used, a dosage of ¾ ounce per thousand pounds of milled rice, with a minimum dosage of 1½ pounds per thousand cubic feet of space, is required with a 15-hour exposure and with the temperature of the rice at 70° F. or over. At lower temperatures and with rough rice the dosage should be increased slightly. The methyl bromide is applied by means of a ¼-inch (outside diameter) copper tube inserted through a hole bored through the car wall or door near the top of the car. The end of the tube in the car should be plugged or pinched together and holes drilled in each side of the tube to allow the fumigant to be forced out toward both ends of the car.

The same precautions should be taken in the application of methyl bromide and in the aeration of the car after fumigation as is required for its use in atmospheric vaults.

Hydrocyanic acid can be used at a dosage of 1½ ounces of liquid hydrocyanic acid or its equivalent per thousand pounds of rice with a minimum dosage of 1¾ pounds per thousand cubic feet of space for a 72-hour exposure.

Dosages of chloropicrin recommended for use in atomspheric-vault fumigation (p. 18) have been found satisfactory in tight railway boxcars. The required dosage can be poured into shallow trays placed on top of the rice. Pieces of crumpled burlap placed in the trays to provide more evaporating surface will aid in speeding up the evaporation.

CONTACT INSECTICIDES

Sprays

Contact sprays are being used rather extensively in rice mills and warehouses, but their value for controlling stored-rice insects is difficult to determine. To be effective the spray must thoroughly cover the insect. Since most insects stay inside the rice packages, covering the packages with a spray and "fogging up" the building at best kills only a small percentage of the insects. Contact insecticides are useful, however, for destroying insects in an empty warehouse when they are sprayed on the walls, floors, and ceilings, but they do not penetrate into cracks filled with dirt or other materials. A very good contact spray can be made by adding 5 percent of a 20-to-1 pyrethrum extract [2] to any good odorless kerosene type of oil.

Dusts

Efforts have been made to use dusts such as lime, finely ground silica, and other chemical substances to protect stored rice. Careful investigation of these has shown that they are of little value unless they are poisonous and therefore unsafe for use on foods.

[2] A 20-to-1 pyrethrum extract is one which contains the pyrethrins extracted from 20 pounds of pyrethrum flowers in 1 gallon of the solvent.

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